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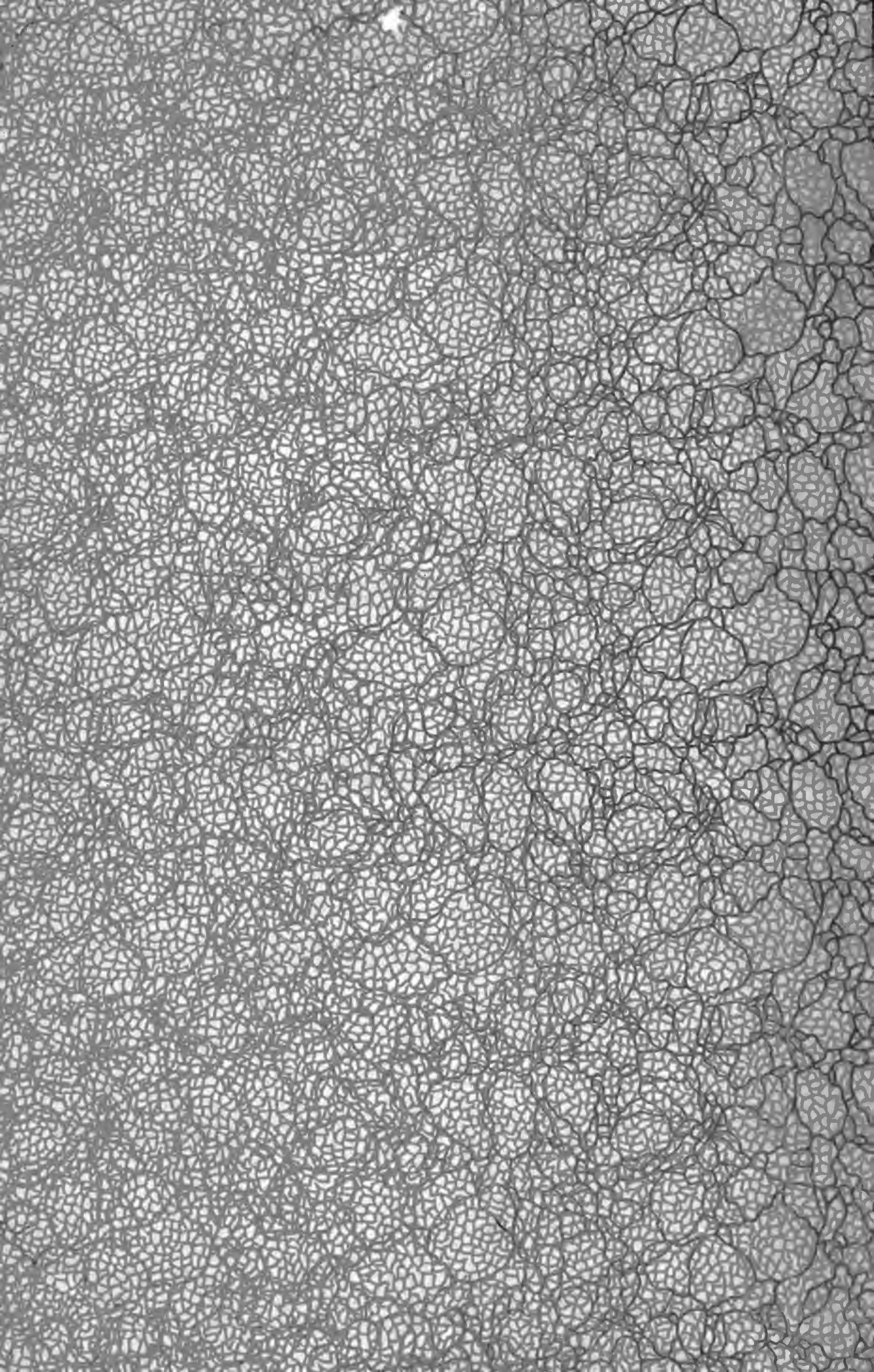

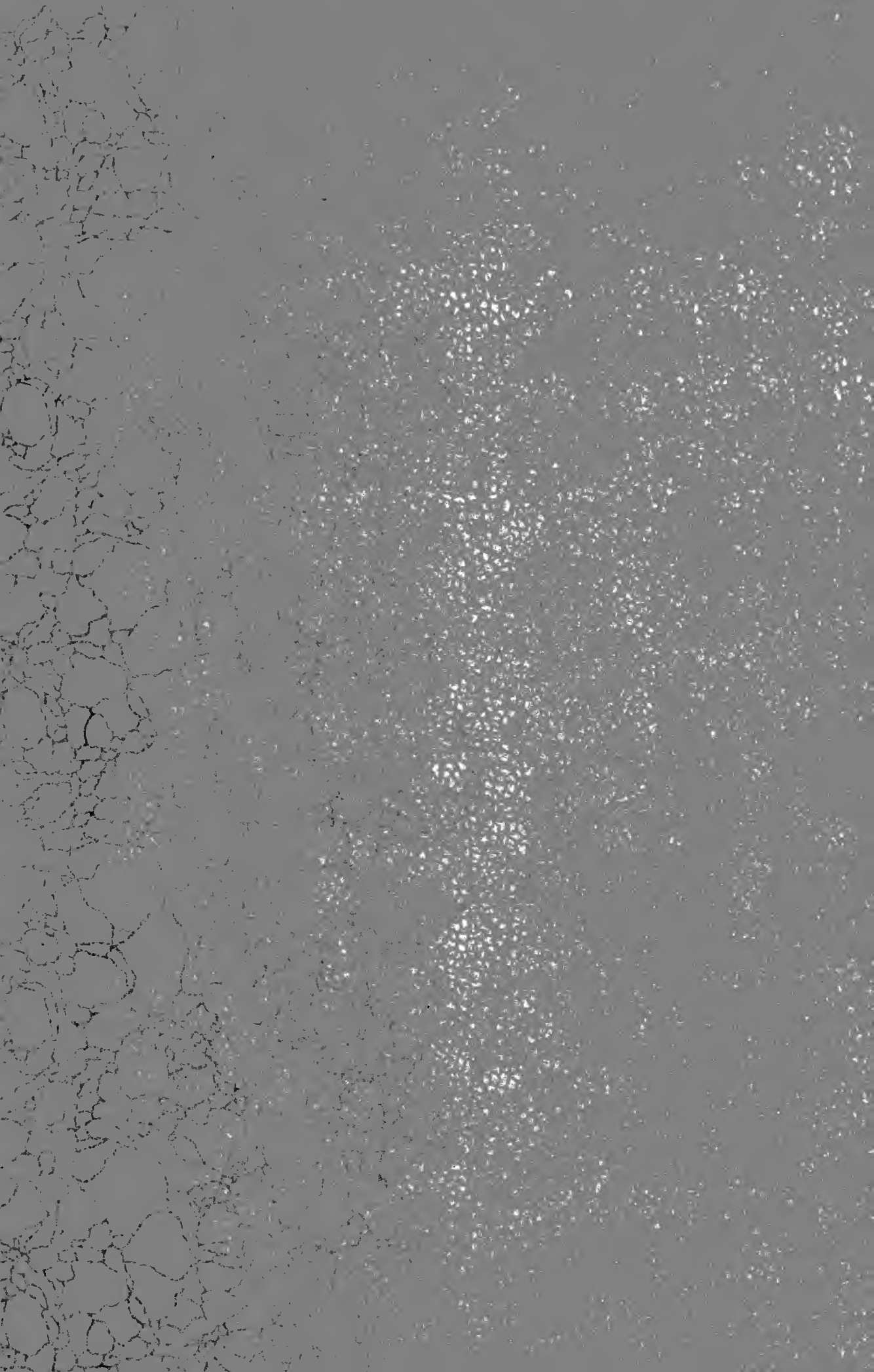

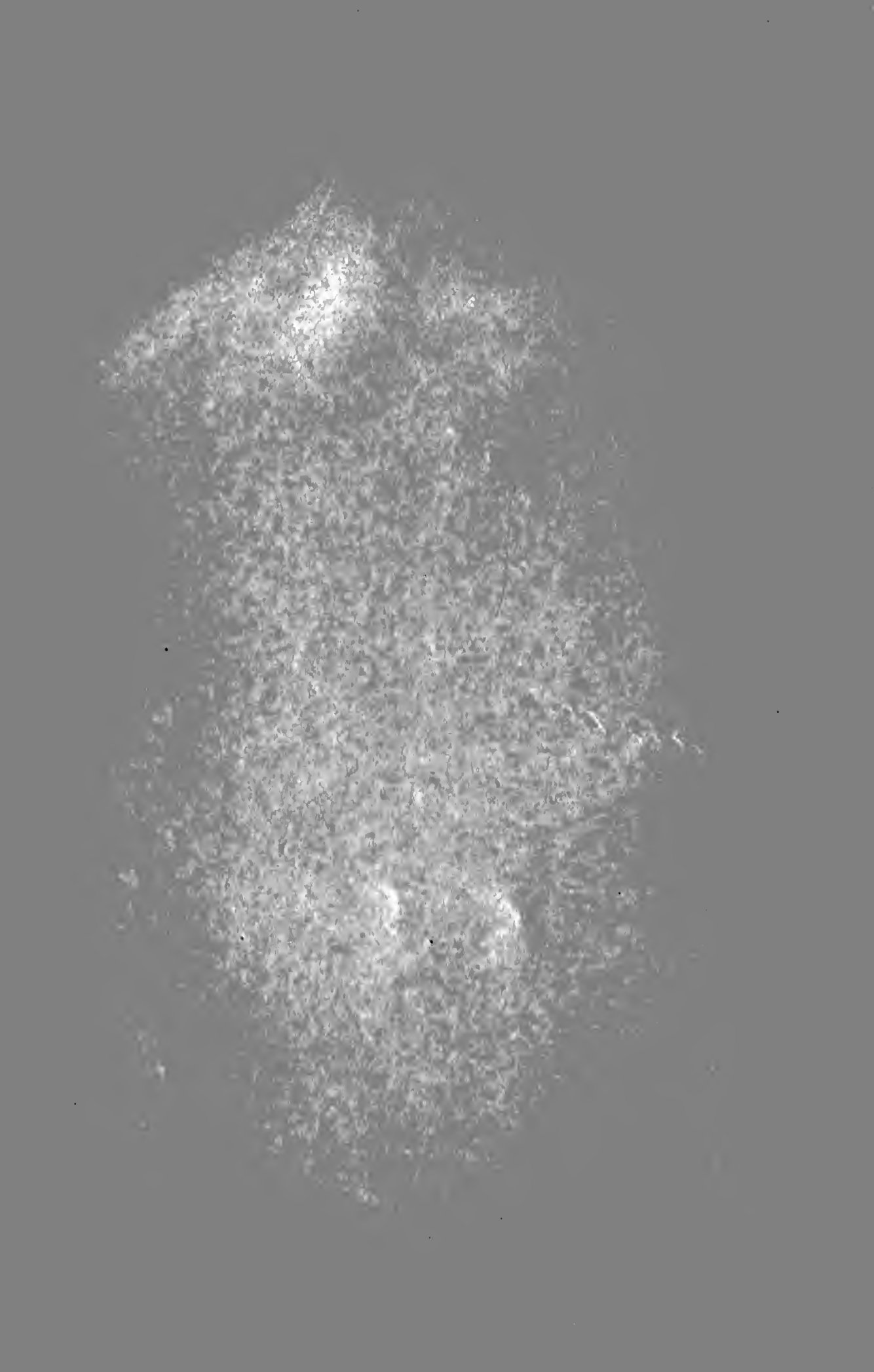

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THE VISIBILITY OF RADIATION. A RECALCULATION OF KÖNIG'S DATA

By P. G. Nutting

Radiation of wave length .61μ (orange red) must be twice as intense as radiation of wave length .54μ in the green to produce the same luminous impression. Similarly radiation in the red at .65μ or in the blue at .47μ must be ten times as intense to produce the same illumination as in the green. By determining the intensities of radiation necessary to produce equal luminous sensations for a number of wave lengths, a complete curve may be obtained having a single maximum in the green and sloping off toward the extreme red and violet. This curve gives the *visibility* of radiation of the various wave lengths.

König investigated the visibility of radiation for his own eye, a normal trichomat, for nine different luminous intensities ranging from the threshold of vision up to about 600 meter-candles per sq. mm of pupil opening. Using a triplex gas flame as a source and a modified prism spectrophotometer, he started with a given intensity in the green at .535 and worked both ways in the spectrum, observing how much the collimater slit had to be opened in order to produce the same luminous sensation as in the green. His observed relative slit widths are given in Table I.

König obtained the spectral energy curve of his gas flame source from Langley and multiplying the above equivalent slit widths by the relative (to 535) spectral energy, took the reciprocal as "Helligkeitswerthe der Energie." These values were recalculated and reduced to maximum ordinate unity to illustrate visibility in the author's paper on the Luminous Equivalent of Radiation.

TABLE I

König's Data on Visibility[1]—Relative Slit Widths

Intensity Steps	T	A	B	C	D	E	F	G	H
Int. (m. c./mm² pupil)	.00024	.00225	.0360	.575	2.30	9.22	36.9	147.6	590.4
Ratio to Preceding Step		9.38	16	16	4	4	4	4	4
Wave Length	Equivalent Slit Widths								
670	296.1	189.0	29.08	14.53	4.56	1.955	1.403	1.23	1.17
650	178.3	87.6	13.9	5.98	1.95	0.991	0.667	0.547	0.420
625	34.8	20.55	6.20	2.93	1.004	0.497	0.392	0.307	0.289
605	12.1	8.60	4.29	2.073	0.869	0.451	0.321	0.289	0.274
590	5.65	4.29	2.75	1.86	0.787	0.523	0.376	0.346	0.330
575	2.76	2.00	1.68	1.42	0.868	0.568	0.449	0.459	0.424
655	1.40	1.232	1.10	1.037	0.876	0.702	0.621	0.603	0.590
535	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
520	1.07	1.09	1.12	1.16	1.40	1.71	1.76	1.77	1.80
505	1.54	1.58	1.59	1.81	2.30	2.78	3.75	4.06	4.46
490	2.34	3.00	3.06	3.33	4.93	7.97	8.91	9.53	10.06
470	5.92	6.49	7.22	7.75	11.0	20.7	22.9	26.6	.....
450	19.21	21.5	20.95	24.2	40.7	57.3	62.9	.....	.....
430	131.6	115.4	85.9	119.2	138.	151.	.....	.....	.....

[1] A König, Helmholtz Festgrüss, Beit. Z, Psych. u. Physiol. d. Sinnesorgane, Hamburg and Leipzig, 1891, pp. 309–388: Verh. d. Physik. Ges., Berlin, **11**, pp. 10–13, 1892: Gessammelte Abhandlungen, Leipzig, 903, pp. 244–213.

König's slit width data are free from objection, but some of his own and the author's [2] deductions from them are wrong. Visibility is the ratio of luminous intensity to energy intensity at each wave length, $V = L/E$. So that to obtain the visibility from constant luminosity data like König's, the relative amounts of energy entering the slit must be known in each case. This energy is the product of three factors—slit width, spectral energy of the source, and relative dispersion. König's original paper (Beit. Sinn. Org.) leaves one with the impression that the prismatic correction was applied, although his prismatic dispersion was not given. Dr. Ives kindly called the author's attention to the fact that this correction had not been made and that König's dispersion curve had later been published (Ges. Abh. Barth,

[2] The Luminous Equivalent of Radiation, this Bulletin, **5**, pp. 261, 308; 1908.

1903). Since these visibility curves are of wide usefulness in spectrophotometry and problems in illumination, they have all to be recalculated to include the correction for variable prismatic dispersion.

In the following table are given for each wave length first the relative spectral energy, the dispersion correction, and the product of these:

TABLE II

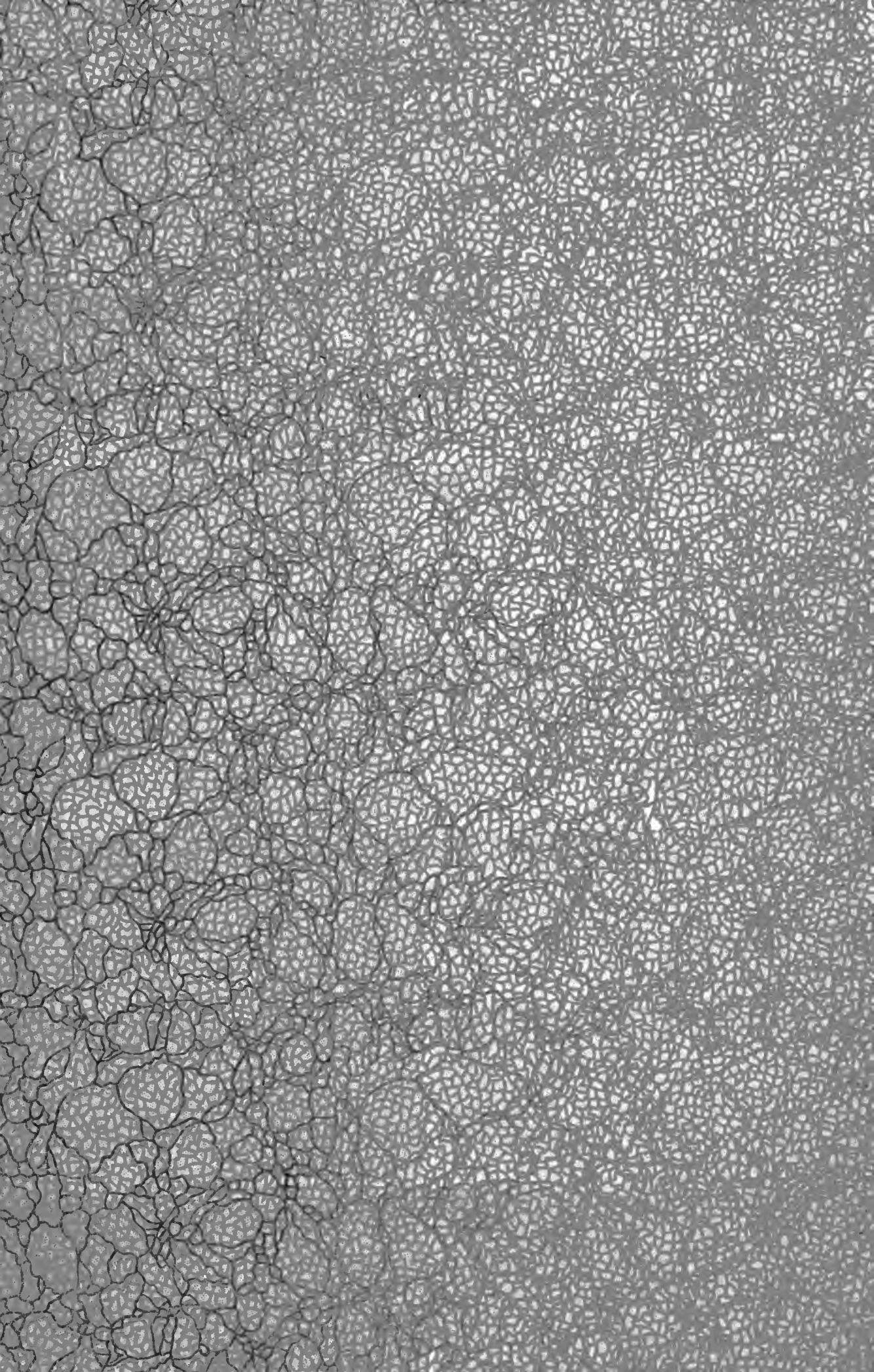
Wave Length	Spectral Energy (Relative)	Prismatic Dispersion (Relative)	Energy Divided by Dispersion
670	13.0	0.649	20.1
650	8.88	0.718	12.38
625	5.38	0.817	6.60
605	3.99	0.909	4.40
590	2.97	0.980	3.03
575	2.27	1.067	2.13
555	1.48	1.222	1.210
535	1.00	1.402	0.712
520	0.720	1.554	0.465
505	0.488	1.730	0.282
490	0.370	1.919	0.193
470	0.251	2.185	0.115
450	0.169	2.462	0.069
430	0.114	2.775	0.041

In obtaining the visibility data of the final table below, the slit widths of the first table were multiplied by the numbers in the last column above. The reciprocals of these products give curves which, when reduced to maximum ordinate unity, are visibilities.

The most marked effect on the visibility curves of the correction for variable dispersion is the shift in the positions of the maxima from .565 to .544μ at high intensities and from .511 to .503μ at the threshold limen (Step T). They are but little affected in width or in general form.

TABLE III

Visibility Reduced Data

	T	A	B	C	D	E	F	G	H
430	.081	.093	.127	.128	.114	.114	.....	.....	.....
450	.33	.30	.29	.31	.23	.175	.16	.....	.....
470	.63	.59	.54	.58	.51	.29	.26	.23	.....
490	.96	(.89)	(.76)	(.89)	(.83)	.50	.45	.38	.35
505	1.00	1.00	1.00	1.00	.99	(.76)	.66	.61	.54
520	.88	.86	.86	.94	.99	(.85)	.85	.85	.82
505	.61	.62	.63	.72	.91	(.98)	.98	.99	.98
555	.26	.30	.34	.41	.62	.84	.93	.97	.98
575	.074	.102	.122	.168	(.39)	(.63)	(.76)	(.82)	(.84)
590	.025	.034	.054	.091	.27	.49	.61	.68	.69
605	.008	.012	.024	.056	.173	.35	(.45)	.54	.55
625	.004	.004	.011	.027	.098	.20	.27	.35	.35
650	.000	.000	.003	.007	.025	.060	.085	.122	.133
670	.000	.000	.001	.002	.007	.017	.025	.030	.030
λ max	.503	.504	.504	.508	.513	.530	.541	.543	.544

WASHINGTON, October 1, 1910.